Problems to be solved with the Gamma Spectrum Generator

1. The measurement setup is similar to the default configuration “NaI, L × D = 1 in × 2 in (default)”. You are going to calibrate it using the 1 MBq ^{60}Co and 1 MBq ^{137}Cs reference gamma sources. Approximately, how many statistical counts can you expect within 100 s in the corresponding gamma-spectra? Make the evaluations with and without backscattered photon contribution.

Answer: ^{60}Co - without backscatter photons $\approx 1.66 \cdot 10^5$ and with backscatter photons $\approx 1.91 \cdot 10^5$, ^{137}Cs - without backscatter photons $\approx 1.06 \cdot 10^5$ and with backscatter photons $\approx 1.18 \cdot 10^5$ counts (use 1 h cooling time after nuclide creation).

2. You have to measure the 10 MBq ^{152}Eu source with NaI (3"×3") scintillation detector in the measurement setup similar to the default configuration “NaI, L × D = 3 in × 3 in (default)”. In your disposal there are three lead filters – 1 mm, 3 mm and 5 mm thick. Find the right combinations of the filters, which would make the measurement possible, assuming that your electronics can cope only with input count rates below 20 kcps (kilo counts per second). Check if the same electronics and filters will allow you to perform the measurement in the configuration “HPGe, coaxial, p-type, rel. eff. 150% (default)”.

Answer: Valid filter combinations: 3 mm + 5 mm (18.8 kcps) and 1 mm + 3 mm + 5 mm (17.2 kcps). The electronics is not suitable for the configuration with 150% HPGe detector since even for the thickest filter combination the predicted input count rate is 22.6 kcps.

3. What is the relative efficiency of the HPGe detector with crystal length – 30 mm, crystal diameter – 50 mm, rear contact length – 20 mm, rear contact diameter – 10 mm, inactive Ge – 1.5 mm, cap thickness – 1 mm Al, and crystal to cap distance – 5 mm? What crystal length doubles the detector relative efficiency?

Answer: Relative efficiency = 10.5%. Crystal length L = 46.5 mm gives 21% relative efficiency.

4. The 1 g natural uranium sample (^{234}U – 0.000055 g, ^{235}U – 0.0072 g, ^{234}U – 0.992745 g) was measured twice on the same NaI (3"×3") scintillation spectrometer (configuration “NaI, L × D = 3 in × 3 in (default)”). The first and the second measurements were performed for 100000 s respectively 10 days and 1 year after the uranium separation. What are the relative contributions of ^{235}U and ^{238}U to the gamma-spectrum measured in both cases? When modeling the spectra, use 1 mm Pb filter to imitate the self-attenuation properties of the sample.

Answer: After 10 days - ^{235}U gives 76% and ^{238}U gives 24%, after 1 year - ^{235}U gives 46% and ^{238}U gives 54%.

5. Based on the gamma-spectrometric examination of a source, the presence of ^{60}Co with activity 100 kBq was revealed. Which of the default GSG measurement configurations are suitable for detecting an additional presence of 50 Bq of ^{241}Am in the same source by performing a 1000 s long measurement?

Answer: Configurations with LEGe and BEGe detectors. The respective MDAs are 12,2 Bq and 18,6 Bq.

Problems to be solved with the EasyMonteCarlo module

1. Calculate the gamma dose and flux rates with respective buildup factors for the 1 GBq ^{60}Co source and 10 cm × 25 cm × 25 cm (thickness × height × width) Pb shield. Source to shield surface distance is 5 cm, detector to shield surface distance is 50 cm.

Answer: dose rate = 3.38 μSv/h, dose buildup = 2.6, flux = 201 1/cm^{2}s, flux buildup = 2.94.

2. Calculate the gamma dose rate at 10 cm distance from the shielded 1 Ci ^{241}Am point source. The iron shield has dimensions 5 mm × 50 cm × 50 cm (thickness × height × width) and positioned in between source and detector. Perform calculations with the default (100 keV) and 10 keV gamma-ray energy thresholds. Explain the results obtained.

Answer: default threshold - 13.1 μSv/h, 10 keV threshold - 244 μSv/h.

3. Calculate the gamma dose rates and buildup factors at 1 m distance from an unshielded 1 Ci ^{152}Eu source. Consider two source geometries: a) point source, and b) uniform distribution in the iron sphere with diameter 5 cm. Explain differences in the build factor values by modeling photon spectral distributions in both cases.

Answer: point source - dose rate = 5.64 mSv/h, buildup factor = 1.01; spherical source - dose rate = 2.96 mSv/h, buildup factor = 1.27.

4. Calculate the neutron dose rate and dose buildup factor at 1 m distance from the 1 Ci ^{252}Cf neutron source. Consider two different shields – 20 cm paraffin and 20 cm lead. Compare dose rate values, buildup factors and contributions of thermal, epithermal and fast neutrons to the full dose rate in both cases. Explain the results obtained.

Answer: Paraffin: Dose rate: total ≈ fast ≈ 2.2 mSv/h, thermal ≈epithermal ≈ 30-40μSv/h BU:4.7
3.2e3 n/cm^2/s (1200 th, 380 epi, 1600 fast), BU = 12.2
Lead: Dose rate: total ≈ fast ≈ 10.4 mSv/h, thermal & epi thermal: neglecting. BU:13.3
1.05e4 n/cm^2/s (10500 fast), BU = 15.1

5. Calculate the neutron dose rate at 1 m distance from a point 14 MeV neutron source emitting 10^{10} neutrons per second. Consider cases of: a) unshielded source, and b) shielded with 10 cm lead source.

Answer: a.) 149 mSv/h, BU=1.01 b.) 87 mSv/h, BU=3.50